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APOLLO MONTHLY PROGRESS REPORT

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31 January 1962

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NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

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FOREWORD

On 28 November 1961, Space and Information Systems Division of North American Aviation was informed that it had been selected as the principal contractor for the Project Apollo Spacecraft. The initial meeting between Apollo representatives of NAA and NASA was held on 4 December 1961 at Langley Field.

Apollo Letter Contract NAS 9-150 was executed on 21 December 1961. For program planning purposes, a go-ahead date of 1 January 1962 was established.

Based upon the Project Apollo Spacecraft Development Statement of Work, 26 separate areas of effort have been defined. This report reflects the progress made in these areas during the first month of program activities.

SUMMARY

The wind tunnel test program has been published; an aerodynamic heating study of the service module, completed; heat-time curves for several design trajectories, established. A method for analyzing the charring ablation process has been developed, and an ablation test program is being conducted.

IBM programs to compute integrated circumlunar trajectories of an earth-moon model, and to determine the conics for a single-impulse abort mission have been written.

Design criteria for waste quantities and use tolerance rates have been established; food configuration, water temperature, and mixing quantity requirements, determined.

Reliability and crew safety requirements have been determined for eight spacecraft subsystems; the launch escape tower design, initiated; the preliminary launch escape test plan, formulated. Preliminary static stability derivatives of the launch escape system have been defined. An analog simulation has been used to investigate open-loop dynamic characteristics, and a digital computer program, planned to investigate the abort trajectory.

Preliminary performance and interface specifications for the command and service modules and the adapter have been completed.

Preliminary command module design layouts are being prepared.

The properties of phenolic-nylon have been determined, and ablator-substructure fastening methods, evaluated.

CONTENTS

FLIGHT TECHNOLOGY

AERO-THERMAL WIND TUNNEL TEST PROGRAM

Flight corridors for the spacecraft configurations have been analyzed and the altitude-velocity ranges that will require simulation in the test program, obtained. Performance ranges of wind tunnel facilities are being investigated with Jet Propulsion Laboratories and Cornell Aeronautical Laboratory. Future discussions will be held with AVCO and General Electric.

A wind tunnel program has been published and test activities for the first quarter of 1962, defined. A schedule of coordination meetings held on this subject is shown in Table 1.

The following policy and operating procedures have been established in meetings held with NASA:

Government laboratory coordinator will be Mr. W. C. Moseley, Jr., of NASA.

NASA and S&ID engineering representatives will be present at each test.

NASA will have prime responsibility for test objectives; S&ID for achievement of the test goals.

Within 30 days after receipt of reduced data on each test, S&ID will publish a tabulated data report.

NASA will publish analytical reports on each test series.

THERMAL ANALYSIS

A study of service module boost-phase aerodynamic heating has been completed. Assuming an emissivity of 0.8, maximum temperature encountered on a 0.1-inch thick aluminum outer face was approximately 460 F.

A preliminary test plan for the study of thermal radiation has been submitted, and an analysis of lunar surface radiation has been initiated to support environmental control system and fuel cell radiator designs.

HEAT SHIELD

Heat shield requirements, including heating-versus-time curves, have been established for several design trajectories. A method of analyzing the charring ablation process has been developed, based on the following assumptions:

The char layer, once formed, will maintain a predetermined and constant thickness.

Heat capacity of the char layer is negligible compared to the heat capacity of the gas evolved at the char layer virgin material interface.

Temperature of the gas from the char layer virgin material interface is initially the same as the char temperature and remains thus as it passes through the char toward the surface.

Degradation temperature of the virgin material is constant.

The above method of analysis is being programmed on the IBM 7090. This program will calculate the mass loss, surface char layer temperature, amount of heat conducted through the virgin ablation material and insulation into the cabin, and temperature profile through the ablator and insulation layers.

A detailed ablation test plan is being compiled. This plan will define individual test concepts, objectives, time phasing, and locations. Support elements and equipment requirements, configurations, and quantities will be included; and Government participation plans designated. A computor program will be utilized in calculating the required thicknesses of ablator and insulation materials of the various design missions.

TRAJECTORY

An IBM program has been compiled to compute integrated circumlunar trajectories in a three-dimensional, earth-moon model, using the lunar orbit plane as the reference. These data will satisfy the inertial insertion and reentry conditions of the circumlunar trajectory as a function of the time of month for a given lunar orbit plane inclination to the earth's equator plane.

Data generated from this program will be utilized to study launch requirements for free circumlunar trajectories returning to a specified landing site. The program will also provide initial conditions for nominal trajectories to be employed in error analysis studies.

SINGLE-IMPULSE ABORT MISSION

An IBM FORTRAN program has been compiled to provide restricted two-body, three-dimensional, conic condition data. The program will calculate atmospheric entry data at a specific flight path angle and altitude, aerodynamic cruises and deceleration through a specific range and cruise time, and a landing at a specific site on the rotating earth.

TWO-IMPULSE ABORT MISSION

A restricted, two-body FORTRAN program is being written to solve the two-impulse transfer between a point of one conic and a point on a second conic in a specific time interval or rendezvous. Planned modifications to this program include multiple-orbit transfers and a possible application to GOSS track and entry conditions, regardless of the position of the vehicle at the time of abort.

LITTLE JOE I BOOSTER

Studies have indicated that by proper selection of the available launch variables, the Little Joe I booster can provide the desired Apollo flight test condition. It has been determined that the maximum dynamic pressure for a typical C-1 boost trajectory is 785 pounds per square foot at an altitude of 36,700 feet and at a velocity of 1506 feet per second. Using preliminary drag estimates, the booster, carrying the Apollo and its launch escape system, can travel through this test point 37.7 seconds after launch at an initial launch elevation angle of 86 degrees. To achieve this point, using a zero-lift trajectory, the second pair of Castor motors can be ignited 8 seconds after ignition of the first pair of Castor motors and the four Recruit motors.

Separation of the command module from the Little Joe I booster presents a problem because of the required high thrust-to-weight ratio of the vehicle. Studies have indicated that it may be necessary to incorporate Little Joe I retro rockets or motor destruct packages to achieve positive separation.

PLANNED ACTIVITIES

Support to the wind tunnel test program will continue through the next month. Planned efforts include the publication of model requirements with the types and locations of end-point instrumentation and descriptions of the models.

Thermal analysis activities will include finalization of the aerodynamic heating test plan.. The test program is scheduled to be initiated during the next report period.

Heat shield insulation and ablation analyses will be extended to include parametric studies for determining the most important factors in the charring ablation process. Existing techniques for predicting aerodynamic heating rates will be studied for Apollo applications.

Technical evaluation of subcontractor proposals supporting the heat shield development program will be completed during the next report period.

INTEGRATION AND SYSTEMS ANALYSIS

PERFORMANCE AND INTERFACE

Preliminary performance and interface specifications for the command module, the service module, and the adapter have been prepared.

SYSTEM ANALYSIS

Trade-off studies have been conducted to determine the optimum configuration for the service module. A parallel study has been made to determine the effects of designing a service module that would be compatible with lunar landing vehicles.

PLANNED ACTIVITIES

Performance and interface specifications for the space laboratory and the lunar module are currently being prepared, and will be finalized during the next report month. These specifications are scheduled for publication in March 1962.

RELIABILITY

QUALITY-RELIABILITY ANALYSIS

A general statement of the Apollo qualification-reliability test program has been completed for inclusion in the Apollo Test Plan. A more definitive qualification-reliability test plan is currently being prepared.

DESIGN ANALYSIS

Spacecraft reliability and crew safety apportionments by mission phase have been completed. System requirements for each phase are being defined.

Preliminary reliability analyses of mission propulsion systems, including failure mode studies and apportionments, have been completed to the component level. Similar analyses of the electrical and environmental control systems are in progress.

Studies are presently being conducted to assess and apportion the influence of ground support equipment on spacecraft reliability and crew safety.

PLANNED ACTIVITIES

Reliability and crew safety requirements for the mission propulsion system and the service module reaction control system will be prepared during the next report period.

INSTRUMENTATION

REQUIREMENTS ANALYSIS

A comprehensive measurement list, itemizing each flight test element and its associated range, accuracy, and response requirements, is being prepared. Recorder studies during the report period have included a review of digital-analog instrumentation merits as opposed to the utilization of separate recorder methods. The applicability of the NASA recorder to Research and Development instrumentation is being investigated.

PLANNED ACTIVITIES

Areas to be studied during the following report period will include modular packaging and standardization, telescope techniques, instrumentation system performance, detailed test requirements, measurement specifications for early test vehicles, and data rate requirements for the sizing of telemetry and tape recording systems.

SIMULATION AND TRAINING

SIMULATION ANALYSIS

Preparation of the training equipment section of the Apollo Ground Support General Equipment Specification has been completed on schedule. An analysis of spacecraft system parameters is currently being made in support of training equipment design and simulation requirements.

TRAINING

An outline of the preliminary training plan was completed.

MOCK-UP

Definitions and schedules for all mock-up requirements have been completed and will form the basis for detail mock-up specifications.

PLANNED ACTIVITIES

Major training activities to be conducted during the following month include the preparation of a detailed analysis of training program requirements and the determination of long lead-time training items. Training equipment specifications defining performance requirements of individual trainers will be initiated in February 1962.

DOCUMENTATION

The preliminary test plan, quality control plan, facilities plan, and spacecraft launch vehicle integration report have been completed and submitted on schedule. A draft of the reliability program plan and the final document revisions method have also been submitted as scheduled.

PLANNED ACTIVITIES

Formulation of procedures to be utilized in negotiating support and maintenance requirements with subcontractors will be completed during the next report month. The preliminary support requirements plan and a detailed procedure to be utilized by S&ID and the subcontractors in development of Apollo support manuals will be finalized during the next reporting period.

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PROGRAM MANAGEMENT

SUBCONTRACT EFFORT

Final work statements have been negotiated with subcontractors for the parachute subsystem, environmental control system, telecommunications system, and the stabilization and control system.

Subcontractor negotiations are in progress to establish requirements for radiation protection, service module propulsion, and ground support equipment.

Request for proposals were submitted to prospective subcontractors for the command module heat shield, earth landing system, and the recovery aids subsystem. Due to recent vendor advancements, requests have been re-submitted to prospective subcontractors for fuel cell system proposals.

Work statements are currently being prepared for the tower jettison rocket motor and life systems requirements.

Reliability and crew safety requirements have been included in the equipment specifications and statements of work for the stabilization and control system, the telecommunications system, the environmental control system, the earth landing system, the main rocket engine and thrust vector control of the launch escape system, the fuel cell subsystem, the command module reaction control system, and the structural heat shield.

Reliability and crew safety requirements are being established for ground support equipment.

Reliability evaluations have been completed for the launch escape motor and thrust vector control proposals received from Lockheed, Aerojet-General, Hercules Powder, Thiokol, and United Technology.

Hardware delivery requirement dates and testing schedules for subcontracted efforts have been prepared in accordance with the latest Make-or-Buy List.

PROGRAM ANALYSIS

Representatives from Collins Radio, AiResearch, Minneapolis-Honeywell, and RadioPlane are currently receiving PERT training at S&ID. Subcontractor network development on specific subsystems has been initiated.

A PERT preparation and approval schedule for 22 networks has been established. All networks are to be completed for final MSC review by 15 May 1962. Network numbering methods, including the proposed MSC system, are being studied for finalization by 6 March 1962.

PROGRAM PLANNING

The official program phasing schedule through final Phase A launch has been released.

PLANNED ACTIVITIES

The S&ID-NASA PERT implementation team will meet every two weeks beginning 20 February 1962.

STABILIZATION AND CONTROL

SUBSYSTEM ANALYSIS

Two pulse-modulation techniques are being studied for use in the Apollo stabilization and control system. One system, proposed by Minneapolis-Honeywell, utilizes pre-programmed pulses which are functions of attitude and attitude rate for large errors, and functions of attitude alone for small errors. The second system utilizes a pulse-modulation scheme in which pulse width and frequency are varied, thereby causing their product to be proportional to the error signal.

The use of the derived rate is being studied as a solution to the limit cycle problems (incurred by rate gyro threshold limitations) and as an aid to system optimization.

The pre-programmed pulse system has been mechanized, and is being tested in conjunction with a PACE TR-10 analog computer to obtain phase plane plots in the limit cycle acquisition phase. The pulse width-and-frequency modulated system is being breadboarded.

PLANNED ACTIVITIES

Planned computer studies for the following report month will include sensor hystereses effects, vehicle dynamics, gas dynamics, and associated areas.

CREW PROVISIONS

WASTE MANAGEMENT

Design criteria for waste quantities and use tolerance rates have been established. An investigation of sponge materials containing skin detergents is being conducted to support bacterial control studies.

FOOD MANAGEMENT AND WATER SUPPLY

The food configuration, water temperature, and mixing requirements have been determined. A review of total water supply has been initiated to determine the quantity and method of water removal from the spacecraft for survival.

The configuration and physical location of the water tanks within the command module present a problem from a standpoint of accessibility and maintenance. A study of the overall water management system has been initiated to determine container capacities, flow rates, and system performance requirements.

SPACE RADIATION SOURCES

Initial space radiation studies are in process to define tentative intensities expected under certain conditions. Some time correlations have been determined for the expected arrival times of solar flare particles at earth-orbital distances. This data has a direct bearing on the warning time available to the Apollo crew.

COUCH DESIGN

Mock-up couch designs have been initiated. The boilerplate designs, based on the mock-up, will serve as the basic lines in the prototype couches. Emphasis is being placed on interchangeability, flexibility, comfort, and support.

PLANNED ACTIVITIES

Development of a more effective design support methodology, completion of life system test plans, release of the preliminary life system design criteria handbook, and the submittal of design criteria specifications to NASA are scheduled for completion during the next report period. A long-duration crew performance test of seven to fourteen days, involving

three human subjects living within the human factors pre-proposal mock-up, is tentatively scheduled for the same period.

Additional studies to be conducted during the following report period will include food package designs, food compartment configurations, and power evasion of heat.

NASA coordination meetings will be held next month to determine acceptable levels of radiation protection. Other organizations concerned with nuclear radiation will be contacted for supporting data.

Computer program applications to the shielding phase and associated areas will also be investigated during February. The IBM 7090 computer programs at the Manned Space Flight Center in Houston, Texas, will be reviewed for analysis of Apollo stopping power applications.

LAUNCH ESCAPE SUBSYSTEM

DESIGN ANALYSIS

Design of the launch-escape tower system has been initiated. Primary emphasis is being placed on the forward connection to the launch-escape motor and the aft connection to the command module.

STRUCTURAL ANALYSIS

The Phase A test plan has been formulated. Test areas will encompass welding, joining, fitting, separation, major static firing, and static firing. A weight trade-off study is being conducted on the escape tower. In this study, two basic steel alloys are being considered, and problems involved with their use are currently being evaluated. These alloys are a high-strength tool steel and a lower strength, more readily fabricated, low-alloy steel.

Requirements indicate the necessity of employing a four-nozzle rocket motor and a four-legged truss. The current location of the jettison rocket, directly below the main rocket, obviates the use of cross members, thus making the torsional stiffness of the four-legged truss a major consideration. This problem will be evaluated during the configuration studies.

Preliminary static stability derivatives of the launch escape system, based on preliminary NASA data and Working Paper 1022, have been defined.

These data include the effects of long and short tower lengths, with a conical shroud encasing the rocket motor nozzles.

A study has been initiated to investigate the feasibility of trimming the effects of the command module offset center of gravity by positioning the nose cone or rocket motor case at an angle of incidence to balance the moment produced by the drag force.

CONTROL REQUIREMENTS

Conclusions of an S&ID flight dynamics study will form the basis for independent investigations to be conducted by the subcontractor and S&ID for the synthesis of a closed-loop control system for controlling abort maneuvers. When these initial investigations have been completed, a preliminary control system will be mechanized for analog computer studies.

FLIGHT DYNAMICS

Digital and analog computer programs, utilizing 6-degree-of-freedom equations of motion, were developed to analyze requirements of the launch escape system. For simplicity, the analog mechanization neglects wind shear effects and assumes a constant Mach number 10.3 for pad abort and 1.57 for maximum dynamic pressure abort.

To judge the effectiveness of the overall launch escape system as simulated on the analog, the following design criteria in their order of importance will be adhered to: altitude and range off the pad; separation distance from the booster at maximum dynamic pressure; and load limits caused by thrust and aerodynamic forces.

The analog simulation has been used to evaluate the preliminary requirements for the launch escape system main escape motor, and to determine the effort of varying the main thrust offset angle. Open-loop dynamic characteristics have been investigated. To determine the need for a closed-loop control system, various amounts of static stability during thrusting have been tried during abort at maximum dynamic pressure. For the thrust vector through the nominal center of gravity prior to ignition, excessive angles of attack are reached in less than 3 seconds when neutral static stability during thrusting is assumed.

PLANNED ACTIVITIES

In the next report month, a three-axis control system will be added to the analog mechanization. Various control parameters, including those considered by NASA (lateral acceleration and body rotational rate), will

be investigated. In addition, the effect of uncertainties in system parameters such as thrust, total impulse, and aerodynamic derivatives will be determined.

Work will be initiated in the near future on a more complete, 6-degree-of-freedom analog mechanization. This mechanization will incorporate wind shear effects and aerodynamic data as a function of Mach number in addition to the parameters simulated in the present analog mechanization.

During the coming months, the primary design efforts will be expended on configuration studies and material selection. The final configuration will be determined by 1 March 1962, and the structural material selected by 1 April 1962.

ENVIRONMENTAL CONTROL

A preliminary development and performance test plan has been prepared for the environmental control system and the gas storage system.

WEIGHT ANALYSIS

Excluding the weight of water storage tanks, a total of estimated component weights, based on information presented by AiResearch, is approximately 425 pounds. An estimated 75 pounds of ducting, tubing supports, and bracketry is required to install the above components.

PRESSURE SUIT REQUIREMENTS

Upon receipt of pressure suit data from NASA, a comprehensive design approach for the suit air supply circuit will be formulated.

PLANNED ACTIVITIES

During the next month, preliminary design installation drawings will be prepared. The installation drawings will depict locations of major components within the command module.

The preliminary work statement for the gas storage system is scheduled to be released to prospective suppliers in February 1962.

EARTH LANDING SYSTEM

IMPACT ATTENUATION SUBSYSTEM

The impact attenuation subsystem is being re-evaluated. The use of air bags for impact attenuation of 16 g's has been proposed for the command module. Studies at NAA and NASA indicate possible advantages can be gained by the use of another type of impact attenuation at other rates of deceleration. To develop an optimum command module impact attenuation design, a trade-off study is being conducted. This study will consider the reliability, weight, volume, schedule, and cost of each type of impact attenuation system. The effect of that system on the command module and systems will also be considered. Design criteria studies will include the investigation of air bags, retro-rockets, shock struts, and destruction of crushable and frangible materials.

PLANNED ACTIVITIES

Re-evaluation of the impact attenuation subsystem is scheduled for completion during the following report period.

COMMUNICATION SUBSYSTEM

SUBSYSTEM ANALYSIS

Analytical studies for the application of various digital concepts to the instrumentation, voice, and television data systems are currently being conducted.

The test objectives of each boilerplate test vehicle have been studied to determine telecommunication equipment requirements. Weight and power requirements have been established from analysis of the telecommunication data.

TELECOMMUNICATIONS EQUIPMENT

Telecommunications equipment requirements for the command and service modules have been reviewed. Special attention was given to the need for equipment accessibility, reliability, and compatibility with supporting items. Size, weight, and location of equipment within the command module and the service module have been tentatively established.

PLANNED ACTIVITIES

During the following report period, studies on antenna requirements for the Research and Development spacecraft will include a more detailed evaluation of the programmed NASA design. A detailed evaluation will be made of alternate approaches for the VHF discone antenna. Efforts will be initiated on procurement specifications for operational antennas.

A preliminary analysis of the requirements for an updated decoder will be started. Trade-off parameters for digital and analog television will be investigated. Development and test planning will be intensified. A more detailed investigation of the requirements for PCM telemetry systems will be made. Further studies of the relative merits of C-band phase wobbulators and of a dual beam system will be conducted.

A meeting with the MSC at Langley AFB will be held during the following report period to establish a plan for the development of Apollo antenna systems.

NAVIGATION AND GUIDANCE INTEGRATION

CRITERIA AND TEST PLAN

Specific task requirements for accomplishing navigation and guidance system integration, checkout, performance evaluation, operation, and generation of performance criteria for system acceptance have been established.

A preliminary outline for the testing of navigation and guidance components, subsystems, and systems has been completed.

Studies of various ascent guidance techniques for applicability to the Apollo launch, abort, and injection phases are being made. A preliminary outline of the basic characteristics of various techniques has been prepared.

A preliminary study of the Massachusetts Institute of Technology midcourse correction technique is being made to evaluate its basic assumptions, approach, mechanization, performance, and problem areas.

Facility requirements for the evaluation of the guidance, navigation, and radar systems are being established.

COORDINATION

S&ID representatives attended Apollo navigation and guidance conferences at the Massachusetts Institute of Technology. At the initial meeting, an administrative agreement was formulated to provide methods for coordination between S&ID, MIT, and NASA. This agreement outlines methods for the conduct of management and technical meetings, correspondence and coordination procedures, interface controls, and industrial subcontractor relations.

PLANNED ACTIVITIES

The exchange of technical and other contractual data during the following report months will follow outlines formulated at the MIT meetings.

COMMAND MODULE STRUCTURE AND SUBSYSTEMS INSTALLATION

PROTOTYPE DESIGN ANALYSIS

Preliminary layouts have been initiated to define the shape and configuration of the crew compartment. Additional requirements and limitations imposed on the command module include reduction in diameter, Paraglider compatibility, 250 pounds of radiation protection water, redundant propellant tankage for the attitude control system, and an increase in system weight and volume requirements. The crew compartment has been reduced from 430 cubic feet (NAA mock-up and quoted NASA 1015 study) to 336 cubic feet. Studies have indicated that the equipment located in the crew compartment will have an installed density of 26 to 34 pounds per cubic foot, depending on the final weight. As 30 pounds per cubic foot is an acceptable density factor which can be obtained by careful packaging, the present volume available in the 154 inch diameter Command Module is adequate.

Additional layouts are being prepared to define equipment requirements in the aft compartment, including high-pressure Paraglider inflation containers, water and urine containers, and a complete attitude control system. Layouts, depicting the position and orientation of the three crewmen during the various phases of flight, have been completed.

Structural layouts are in progress for the inner and outer structures. Basic load paths for the inner structure, access door requirements through the outer structure, and the three-side wall hatches for crew entrance and exit have been tentatively defined. Methods of manufacturing subassembly

units and high load attachment areas have been defined. The present configuration of the inner structure is of bonded aluminum honeycomb, and the outer structure is of high temperature, brazed steel honeycomb.

STRUCTURAL ANALYSIS

The structural test plan for phase A has been formulated. The tests, outlined in this plan, include heat shield design development tests, heat protection system-structural integration tests, structural development and qualification tests, major static tests, and a boilerplate-proof test. The test program initiated during the proposal interim period has been completed and the final report, SID 62-9, has been published. In this program, phenolic-nylon physical and mechanical properties were determined, and ablator-substructure fastening methods were evaluated.

To provide redundancy to the heat protection system, an ablative substructure capable of withstanding temperatures up to 2000 F is being considered. A study is being conducted to determine the ablative substructure material choice.

WEIGHT ANALYSIS

AMPR and cost analysis weight data have been generated for all boilerplates and prototypes. Preliminary system definitions indicate the necessity of weight increases in the initially planned components. Additional components will also be required. Early estimates indicate that an installation density of at least 30 pounds per cubic foot must be achieved. Individual component weights are being studied, and any additional component weight increases will be justified.

A weight trade-off study is being conducted to aid in the selection of the pressure vessel configuration. Initial results indicate little difference in weight exists between the skin-stringer and the ring-reinforced approaches. A bonded sandwich shell appears to be approximately 30 percent lighter than the single wall configurations. Detailed studies of the weight penalties associated with cutouts, hatches, and other local effects are in progress.

MANUFACTURING

The Bonding and Processing Facilities Building is being designed. Construction has been scheduled to be completed in July 1962. The primary building structure will be 100 by 180 by 50 feet, with an extension on the side of 30 by 180 by 24 feet.

A boilerplate manufacturing schedule has been established. The initial eight boilerplates are to be completed by December 1962. The remaining nine articles will be completed by June 1963. The first command module prototype manufacturing schedule has been initiated with the publication of the assembly breakdown and tooling bar charts. The prototype manufacturing assembly sequence is currently being established. In conjunction with this schedule, a detailed analysis of the brazing process for the floor and outer heat shields has been conducted to determine overall leadtimes required for procurement purposes.

BOILERPLATE VEHICLES

The design effort, including a structural assembly drawing for Boilerplate Vehicle No. 1, has been initiated. Structural steel will be utilized for fabrication of the vehicle.

Preliminary studies indicate that the C-133B airplane is the only aircraft large enough to carry Boilerplate Vehicles No. 3 and No. 5. The C-133A airplane would be limited to carrying the boilerplate vehicles in the aft ramp area and in a partially exposed condition. The C-133B airplane can either carry the boilerplate vehicles internally or partially exposed to support air-drop requirements. Extensive aerodynamic and structural studies will be required to utilize the C-133 airplane for this type of mission.

High energy forming and spin forging methods are being evaluated for the forming of pressure vessels.

PLANNED ACTIVITIES

Further studies will be made in the following report period to evaluate an aluminum-bonded honeycomb skin versus a single-wall reinforced skin for the command module inner structure.

Problems associated with a shingled substructure approach and a conical shell substructure approach will be investigated during the next report period. Several L-605 brazed honeycomb panels have been fabricated for the purpose of evaluating the heatshield substructure approach. These panels will be tested to determine their mechanical properties and their compatibility with various fastening methods. Panels with and without ablative coverings will be tested under combined load and temperature restrictions in the radiant heat facility.

SERVICE PROPULSION SUBSYSTEM

PROPELLANT REQUIREMENTS

The major propulsion development problem appears to focus on achieving a burning time of 500 to 600 seconds with minimum thrust erosion and chamber wall thickness.

The solid propellant called for in the original proposal has been replaced by a storable, hypergolic propellant. Configuration studies have been made to support trade-offs of the liquid systems. Configurations studied included propulsion furnished by single and multi-engines, and propellants stored in single and multi-tanks. The multi-tank configurations offer offloading capabilities for alternate missions.

PLANNED ACTIVITIES

During the following report months, further engine studies will be initiated on three additional configurations: a single engine with toroidal fuel and oxidizer tanks; a single engine employing multi-cylindrical common bulkhead fuel and oxidizer tanks; and multi-engines with multi-cylindrical fuel and oxidizer tanks.

A study of the single engine and multi-engine configuration will be continued. Major factors in the study include reliability, relative performance, vehicle compatibility, developmental effort, effect on trajectory, crew display requirements, and overall weight.

SERVICE MODULE STRUCTURE AND SUBSYSTEM INSTALLATION

STRUCTURAL ANALYSIS

A test plan for the phase A portion of the program depicted on the development schedule has been completed.

Six structural configurations have been investigated to establish preliminary weight trade-off data, and to furnish supporting information on structural materials and gauges being considered for component parts.

The three configurations resulting from the original investigation are being analyzed to provide updated weight trade-off data, and to further define structural requirements.

The three types of pressure vessels currently under consideration are spherical, cylindrical, and toroidal. The spherical tank is the lightest container. The cylindrical tank is 25 percent heavier than the spherical tank, and the toroidal tank, utilizing titanium fabrication, is 60 percent heavier than the spherical tank.

PLANNED ACTIVITIES

Material considerations for the three pressure vessels will be further analyzed during the next report period. Many problem areas are presented by the utilization of titanium in fabrication of the toroidal tank. The second most desirable material has a strength-to-weight ratio approximately 25 percent less than titanium. The toroidal tank would be nearly 110 percent heavier than the spherical tank.

ELECTRICAL POWER SUBSYSTEM

FUEL CELL ANALYSIS

An evaluation of performance characteristics of the fuel cell system is currently being made. A study is being conducted to assess the amount of inert contaminants that may be permitted within the reactants. A revised load profile has been tabulated to permit vendor proposals based upon a more current description of the Apollo vehicle.

An analysis of the radiator system to be used with the fuel cells has been initiated. This analysis is employing a computer program for space radiator systems.

A preliminary list of requirements for various boilerplate vehicles has been prepared. These requirements encompass both wiring and electrical loading. A list has been prepared of points within the fuel cell and power distributions systems requiring transducers for inflight test, monitoring, and ground check-out. A tentative layout of electrical equipment with minimum wire runs has been prepared.

A preliminary test plan has been completed to delineate test item requirements and testing schedules. A physical layout of the fuel cell test building has been prepared.

POWER DISTRIBUTION SYSTEMS

Studies are presently being made to determine the desirability of employing standard wiring bundles as opposed to utilization of ribbon tape conductors. Ribbon tape conductors show promise of weight saving for control circuitry.

A systems schematic has been prepared to permit a reliability analysis of the depicted redundancy.

PLANNED ACTIVITIES

Fuel cell system proposals are due to S&ID during the next month, and evaluation will commence as soon as the proposals are received.

REACTION CONTROL

SUBSYSTEM ANALYSIS

Preliminary schematics of the command module reaction subsystem have been completed.

Primary problems of the command module reaction control engine have included determination of the minimum impulse requirement, the thrust transient rates, and the operational life requirements. These parameters have been resolved by S&ID and Minneapolis-Honeywell.

PLANNED ACTIVITIES

A study to determine the re-entry environmental temperature applicable to the engine will be continued in the following report period. The temperature will influence the choice between an ablative or a radiation cooled chamber.

Information is being accumulated for a preliminary specification to define design requirements for the service module. The specification is scheduled for completion in the next report month.

SPACECRAFT ADAPTER DESIGN-FABRICATION AND ASSEMBLY

A test plan for the phase A portion of the program has been completed.

Preliminary structural requirements for the Little Joe boilerplate adapter are being determined.

GROUND SUPPORT EQUIPMENT

SPECIFICATIONS

Preparation of the following specifications has been initiated:

GSE specification, SID 62-50, will define the general performance requirements for the spacecraft GSE, the major areas in which this GSE is required, and the operations to be performed by each GSE item.

GSE Performance and Interface Specification, SID 62-57, will define the function, performance, conformance, and interface of each item of GSE.

GSE Design Criteria Specification, SID 62-65, will define the complete design criteria for all Apollo GSE.

STATIC FIRING FACILITY

The selection of a site for the Static Firing Facility is currently being investigated. Preparation of facilities criteria for the Apollo AMR operations has been initiated.

PLANNED ACTIVITIES

A study of point-to-point communications and its related effects upon the operational control concept is currently being planned. A study on time of the month flexibility of Pacific entry landings from a lunar mission will be continued in the following report month.

Specifications for GSE items are scheduled for completion during the following report month.

Detailed systems analysis and configurations of GSE items will be initiated in February 1962.

GROUND OPERATIONAL SUPPORT SYSTEM (GOSS)

TELECOMMUNICATIONS ENGINEERING REPORT

Telecommunications Engineering Report, TER-62-1, was revised and expanded during the report month.

Table 1. Meetings

Date	Location	Subject	North American Representatives	Organizations Represented
1-4	Ames Research Center, San Francisco	Wind Tunnel Program	McNary	NAA, Ames Research
1-8/1-11	NASA, Langley	Antenna Meetings for R & D Flights	Chinn Bologna Page	NAA, NASA, Johns-Mansville
1-15/1-18	MIT, Boston	Navigation and Guidance	O'Malley Beck Cole	NAA, NASA, WESCON
1-16/1-19	NASA, Langley	GOSS Discussions	Ferrier Goen Pope	NAA, NASA, Lincoln Lab
1-16/1-18	NASA, Langley	Antennas	Rousculp	NAA, NASA
1-17/1-18	NASA, Langley	Test Facilities	McKim	NAA, NASA
1-20/1-24	Chicago Midway, Labs, Chicago; Ames Research Center, San Francisco	Ablative Material Review	Gershun Wykes	NAA, NASA, Chicago Midway Lab, Ames Research
1-23	NASA, Langley	Navigation and Guidance	Allen McNary	NAA, NASA, MIT
1-24/1-26	NASA, Langley	Apollo Discussion	Ball	NAA, NASA

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Date	Location	Subject	North American Representatives	Organizations Represented
1-24/1-26	NASA, Langley	Wind Tunnel Program	Bannerman McNary Allen	NAA, NASA
1-24/1-26	NASA, Langley	Landing Impact Study	Brayton	NAA, NASA
1-25/1-29	Cape Canaveral	Observe Mercury Launch	Feltz Paup	NAA, NASA, participating and interested organizations
1-25	NASA, Langley	Wind Tunnel Coordination	Gildea	NAA, NASA
1-30/2-1	MIT, Boston	Navigation and Guidance, Technical Coordination Meeting	Cole Dale Kennedy Beck Steiner	NAA, NASA, MIT, participating and interested organizations
1-31	Ames Research Center, San Francisco	Pre Test Conference	Allen	NAA, Ames Research
1-31/2-1	New York	AIEE Paper	Miller	NAA, participating and interested organizations